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Analysis and design Rectangular patch with half Rectangular Fractal Techniques

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Abstract

In this paper, rectangular patch with half rectangular fractal geometry is designed. The proposed antenna is fabricated on RT/duroid 5880 with relative permittivity 2.2 and having dimensions 40mm x 30mm x 1.56mm. HFSS software is used for the design of this antenna. It operates at four frequency bands 3.19-3.29 GHz, 3.98-4.09GHz, 5.4-5.46GHz and 5.97-6.06GHz. The proposed antenna can be used in the military for meteorological purpose and satellite communications. The proposed design has return loss –18.5061dB, -22.1394 dB, -4.7404 dB and -36.2199 dB in frequency bands 3.19-3.29 GHz, 3.98-4.09GHz, 5.4-5.46GHz and 5.97-6.06GHz.

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*Keywords :*microstrip; antenna; return; loss; frequency; gain; iteration;

1. Introduction

In modern wireless communication need for small sized compact wideband and multiband antennas have raised. Normally an antenna operates at single or dual frequency bands. So according to the requirement the antenna is designed. Hence sometimes the problem with the size of antenna arises. To overcome this multiband antenna is used. In this a single antenna is made to operate at many frequency bands. This is designed by applying fractal shape into the antenna geometry [1]. The main requirement for modern communication systems is small size and wideband antennas. Fractal geometries have been used to fabricate multi-band and broad-band antennas. By the design of

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fractal geometry the perimeter of antenna increases hence large surface area is available for radiating or receiving the electromagnetic radiations [2].

To fulfill the requirements of low profile, low cost, small size, ease of fabrication and multiband characteristics, microstrip antenna are employed [3]. The commonly available shapes for microstrip antenna are rectangular, square, oval, elliptical etc. When we compare microstrip antennas with conventional antennas then more advantages are offered by microstrip antennas. A number of miniaturization technique such as high dielectric substrate [4], reactive loading [5], increasing the electrical length of antenna by optimizing its shape [6] have been proposed. The main application of fractal antenna is to reduce the overall geometrical size [7].

There are a number of available shapes for fractal antenna such as Sierpinski carpet, Sierpinski gasket, Koch, Hilbert curves etc that are meant for designing the antennas. Their main purpose is to increase the electrical length of antenna without affecting the radiation characteristics of the conventional antenna. The space-filling properties of some fractal shapes the fractal dimension might allow fractal shaped small antennas better to take advantage of the small surrounding space [8].

2. Design of Antenna

For the design of rectangular microstrip antenna there should be knowledge of resonant frequency (f_r), dielectric constant of material (ε_r) and height of substrate (h). Proposed antenna is designed at 3.2 GHz resonant frequency.

Patch width of antenna is calculated by using transmission line model equations as given in [12-14].

$$W = \frac{1}{2 f_r \sqrt{\mu_0 \varepsilon_0}} \sqrt{\frac{2}{\varepsilon_r + 1}} = \frac{v_0}{2 f_r} \sqrt{\frac{2}{\varepsilon_r + 1}} \tag{1}$$

ε_r= 2.2 (Rogers RT/duroid)
f_r = 3.2GHz
Co = 3x10^8 m/sec
With this equation the width comes to be, W= 21.94 mm
Effective dielectric constant of material is calculated using equation as given in [12-14]:

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left[1 + 12 \frac{h}{W} \right]^{-\frac{1}{2}} \tag{2}$$

Effective length of patch is calculated using equations as given in [12-14]:

$$\Delta L = h \frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264 \right)}{(\varepsilon_{reff} - 0.258)\left[\frac{W}{h} + 0.8 \right]} \tag{3}$$

$$L_{eff} = \frac{1}{2 f_r \sqrt{\varepsilon_{reff}} \sqrt{\mu_0 \varepsilon_0}} - 2\Delta L \tag{4}$$

Effective length becomes, L= 28.53 mm

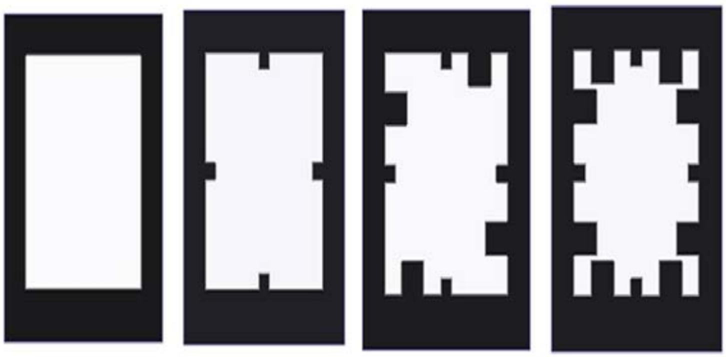
Design steps of proposed antenna are given below:

Step 1: Design of proposed antenna starts with rectangular geometry whose dimensions are calculated by using equations 1 to 4. These dimensions at resonance frequency 3.2 GHz for RT/duroid material with dielectric constant 2.2, height 1.56 mm are found 28.53 mm x 21.94 mm. This geometry is 0^{th} iteration of the antenna. It is illustrated in figure 1 (a).

Step 2: A half rectangle with dimension 2mmx 2mm is subtracted from the middle of four sides of rectangular patch geometry of 0^{th} iteration to get the 1^{st} iteration as shown in Figure 1 (b).

Step 3: A half rectangle with dimension 4mm x 4mm is subtracted towards the left side of the already cut slots in the 1^{st} iteration to get 2^{nd} iteration as shown in Figure 1 (c).

Step 4: A half rectangle with dimension 4mm x 4mm is subtracted towards the right side of the first iteration to form the 3^{rd} iteration as shown in Figure 1 (d).



(a) (b) (c) (d)

Fig. 1. Various iterations of proposed antenna (a) 0^{th} iteration (b) 1^{st} iteration (b) 2^{nd} iteration (d) 3^{rd} iteration

Different feeding techniques can be used in the designing of microstrip antenna. These are microstrip line [9], coaxial probe [10], coplanar waveguide [11] etc.

In this paper, coaxial probe is used for feeding purpose. In the coaxial probe, inner conductor of coax is attached to the radiation patch while outer conductor is connected to ground plane. The advantage of coaxial probe is easy to proper impedance matching with antenna. It also has low spurious losses.

3. Simulation Results

Simulated results for the four iterations are shown in Figure 2. When fractal techniques are applied on the rectangular patch, improvements in results are found in successive iteration stage. Blue curve indicates the 1^{st} iteration. Red curve indicates the 2^{nd} iteration. Black curve illustrates the 3^{rd} iteration. Green curve indicates the 4^{th} iteration. 3D radiation pattern of proposed antenna for 0^{th}, 1^{st}, 2^{nd} and 3^{rd} iterations at respective resonant frequencies are shown in Figures 3, 4, 5 and 6 respectively. Different performance parameters of proposed antenna such as return loss, gain and bandwidth for 0^{th}, 1^{st}, 2^{nd} and 3^{rd} iterations are calculated and their numerical values are shown in Table-1.

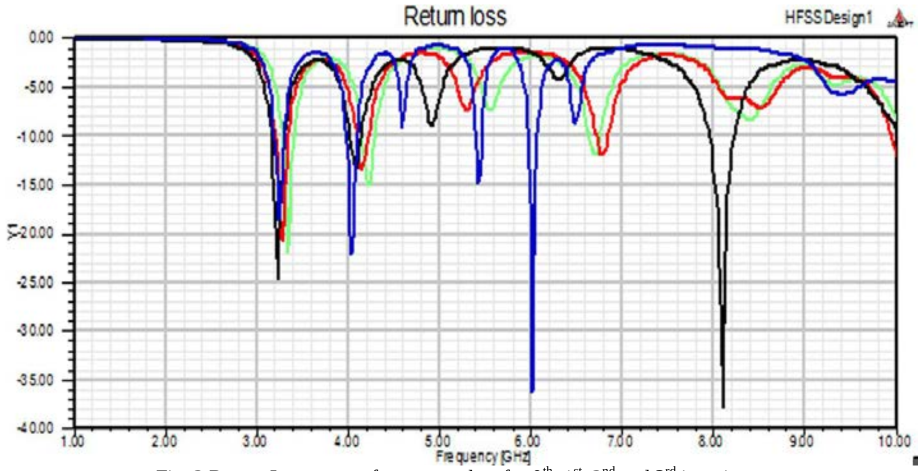
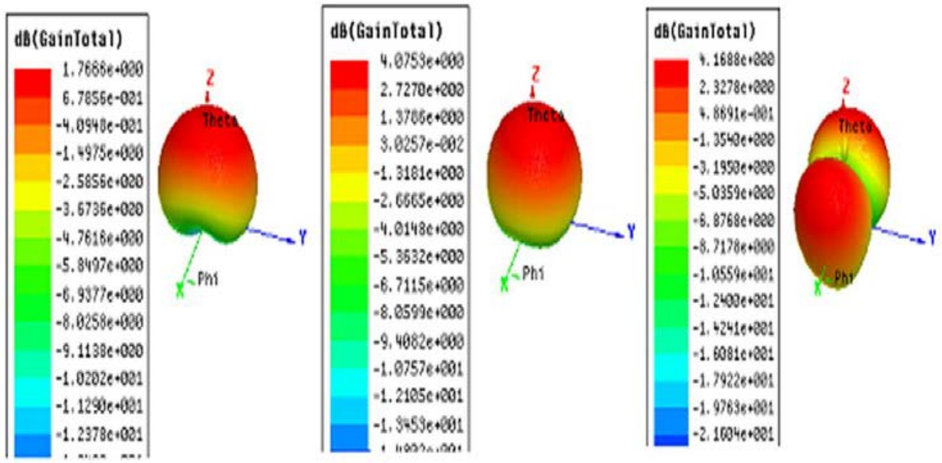


Fig .2.Retrun Loss versus frequency plots for 0th, 1st, 2nd and 3rd iterations

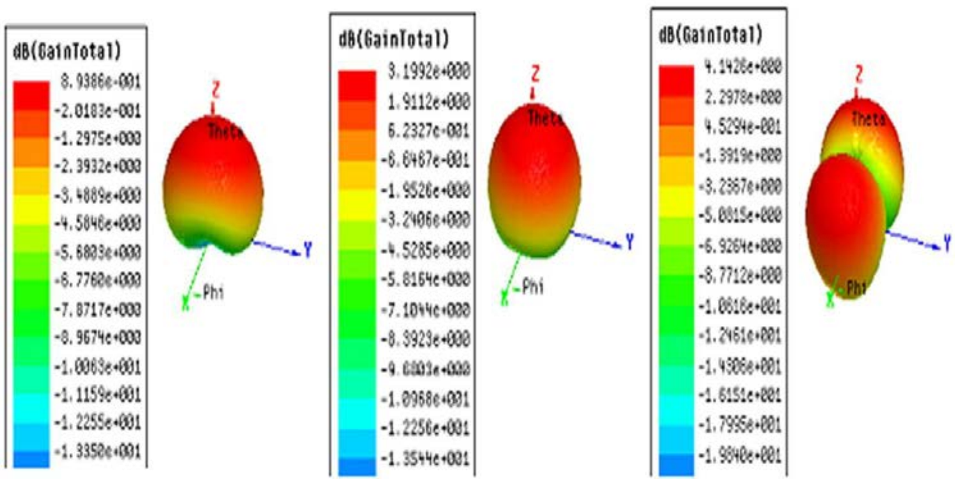
Table 1. Various performance parameters for simple patch

Iteration	Frequency (GHz)	Return loss (dB)	Gain (dB)	Bandwidth (MHz)
0th	3.34	-21.9306	1.7666	134.9
	4.23	-14.8824	4.0753	139.2
	6.70	-12.0012	4.1688	120
1st	3.28	-20.8509	8.9386	140
	4.15	-13.4950	3.1992	130
	6.78	-12.8509	4.1426	130
2nd	3.23	-24.6365	2.5809	210
	4.08	-13.1026	2.5318	130
	8.1	-37.6717	2.2511	280
3rd	3.25	-18.5061	2.1298	100
	4.04	-22.1394	4.3369	110
	5.34	-14.7404	7.7979	60
	6.02	-36.2199	2.9122	90



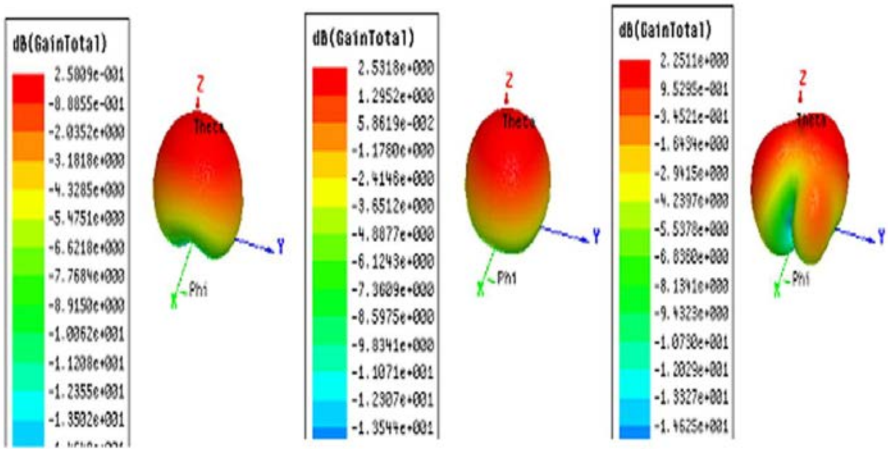
(a) (b) (c)

Fig. 3 3D Gain Pattern of rectangular patch at frequency (a) 3.34GHz (b) 4.23GHz (c) 6.7GHz



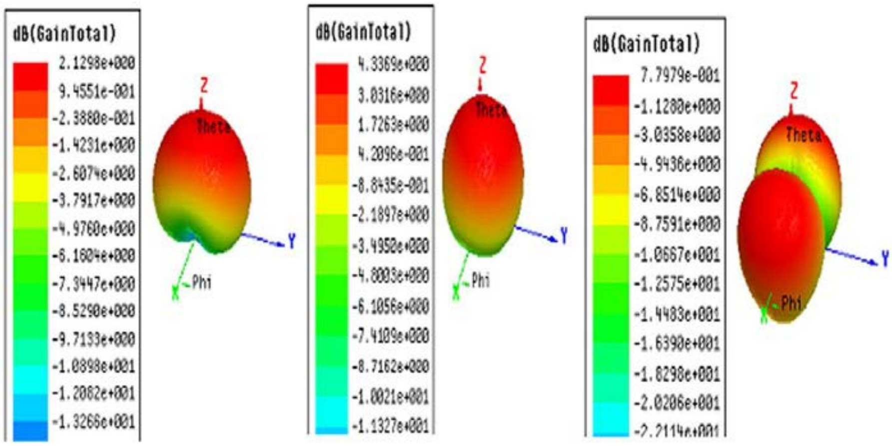
(a) (b) (c)

Fig. 4. 3D Gain Pattern for first iteration at frequency (a) 3.28GHz (b) 4.15GHz (c) 6.78GHz



(a) (b) (c)

Fig. 5. 3D Gain Pattern for second iteration at frequency (a) 3.23GHz (b) 4.08GHz (c) 8.1GHz



(a) (b) (c)

Fig. 6. 3D Radiation Pattern for third iteration at frequency (a) 3.25GHz (b) 4.04GHz (c) 5.43GHz

4. Conclusion

In this paper, Rectangular patch with half rectangular geometry is designed. From the above discussion, it can be concluded that antenna parameters are improved by using half rectangular fractal geometry and coaxial feed line. The proposed design works in four frequency band 3.19-3.29 GHz, 3.98-4.09GHz, 5.4-5.46GHz and 5.97-6.06GHz. It can be employed in weather radar, long distance radio communications, satellite communications and cordless telephony applications.

(d)

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